



# On the rate of return and risk factors to international oil companies in Iran's buy-back service contracts<sup>☆</sup>



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## ABSTRACT

We analyze the rate of return (ROR) and risk factors faced by Shell Exploration, an international oil company (IOC), in its Soroosh and Nowrooz buy-back service contract in Iran. In particular, based on our models of cash flow, we analyze the buy-back contract specific risk factors that can contribute to a reduction in the rate of return for the international oil company. Our cash flow models resemble the cash flow of buy-back service contracts before the Iranian government changed the way it determined the capital cost ceiling and pre-defined the oil price in these contracts in 2008–2009. Our actual and contractual cash flow models reveal that Shell Exploration's actual ROR was much lower than the contractual level. Furthermore, we find that among the risk factors that we considered, a capital cost overrun has the greatest negative effect on the IOC's ROR. Moreover, we show that there is a potential for modifying the contracts in order for the IOC to face an actual ROR closer to the contractual ROR even if the contract faces cost overrun or delay, without exceeding the maximum contractual ROR that the National Iranian Oil Company is willing to give.

## 1. Introduction

In recent years, some oil and natural gas producing countries have shown an increasing interest in adopting variations of service-type contracts rather than production sharing contracts or concessions in their oil and natural gas development and exploration projects (Ghandi and Lin, 2014).<sup>1</sup> A service contract<sup>2</sup> is a long-term contractual framework that governs the relation between a host government and international oil companies (IOCs) in which the IOCs develop or explore oil or natural gas fields on behalf of the host government in return for pre-determined fees and in which in most cases the host

government does not hand over the control of the extracted or subsoil or sub-surface resources to the IOCs (Ghandi and Lin, 2014).<sup>3</sup> One type of service contract is Iran's buy-back service contract.

This paper assesses the risks factors that international oil companies (IOC) face in Iran's oil and natural gas buy-back service contracts and their effects on the IOC's rate of return (ROR) on these contracts. A buy-back service contract is the primary framework that the National Iranian Oil Company (NIOC) uses to engage IOCs in the development of Iran's oil and natural gas fields in order to benefit from the IOCs' expertise and investment. In these contracts, once the fields reach contractual full production level, the operation of the developed fields

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<sup>1</sup> Ghandi and Lin (2014) compare service contracts and production sharing contracts and review the energy strategy and oil and natural gas fiscal systems of eight major oil or natural gas producing countries which have either adopted a variation of a service contract or have shown interest in this framework.

<sup>2</sup> The term service contract can also refer to oilfield service contracts. There are oilfield service firms, such as Halliburton, Schlumberger and Baker Hughes, that provide oilfield services and that may specialize in services such as drilling. These firms are awarded oilfield service contracts to fulfill particular jobs as part of broader development or exploration plans. Sund and Hausken (2012) analyze when an operator and a service provider prefer a fixed price oilfield service contract, common in the oil and gas industry, versus the uncommon incentive-based oilfield service contract. In this paper, we focus on service contracts between host governments and international oil companies, not on oilfield service contracts between an operator and a service provider.

<sup>3</sup> In some variations of service contracts such as Venezuela's third round operational service agreements, the IOCs may enjoy more benefit than usual service contracts in terms of sharing the profit oil, and therefore have some degree of control over the produced crude. However, in general, service contracts do not have a profit sharing mechanism.

is transferred to the NIOC, and the IOC recovers its cost plus additional remuneration fees through an allocation of the developed fields' produced crude based on an agreed-upon targeted rate of return (ROR).<sup>4</sup>

Studies that discuss Iran's buy-back service contracts can be categorized in three groups. The first group, which includes Bindemann (1999) and Marcel (2006), provide basic definitions and some general characteristics of buy-back service contract. Both studies consider this contract as having characteristics that lie in between a service contract and a production sharing contract.

The second group of studies cover more aspects of a buy-back contract, and include Shiravi and Ebrahimi (2006) and van Groenendaal and Mazraati (2006). Shiravi and Ebrahimi (2006) discuss the terms and a history with a brief overview of some possible risk factors for the IOCs in these contracts. Van Groenendaal and Mazraati (2006) further the discussion over risk factors by analyzing the effects of two risk factors, oil price and delay, on the IOC's rate of return. Based on their model of cash flow of a natural gas buy-back service contract, they show the potential of oil price fluctuations and delays in reducing the IOC's rate of return. However, they limit the scope of the study on just these two risk factors with a limited range of possible values for each. Our paper expands upon their study by considering a larger set of possible risk factors including a capital cost overrun, which we find to be an important risk factor.

The third distinct group of buy-back related studies includes Ghandi and Lin (2012), who study the Soroosh and Nowrooz buy-back service contract. Based on a model of dynamically optimal oil production model, Ghandi and Lin (2012) show that the NIOC has not reached its contractual goals, nor has it achieved optimality in either profit maximization or cumulative production maximization. The low level of production can be partially explained by the terms of the contracts (the NIOC operatorship) and the crude share arrangements based on the cash flow calculations (marketing/customer issues) of the buy-back service contracts (Ghandi and Lin, 2012). Ghandi and Lin Lawell (2017) develop a dynamic model of oil production and well drilling to analyze the economic efficiency of oil contracts, including technical service contracts, buy-back contracts, and production sharing contracts.

The unique nature of a buy-back service contract and the fact that the IOC does not share in the profit raise the question of how much the inherent risk due to the nature of the buy-back service contract could affect the IOC's actual ROR. To answer this question, we model Shell Exploration's contractual and actual cash flow in its Soroosh and Nowrooz buy-back service contract as a case study. Our cash flow models resemble the cash flow of buy-back service contracts before the Iranian government changed the way it determined the capital cost ceiling and pre-defined the oil price in these contracts in 2008–2009.

Based on our models of cash flow, we analyze the buy-back contract specific risk factors that can contribute to a reduction in the IOC's rate of return. These risk factors include capital cost, the time profile for capital expenditures, operating and maintenance cost, delay in construction, oil price fluctuations, deviations from the contractual production level, London Interbank Offered Rate (LIBOR) reduction, and finally the remuneration not being realized.<sup>5</sup> Based on our detailed analytical risk-sharing cash flow models, we also propose modifications to buy-back service contracts that enable the IOC to face a lower degree of risk.

<sup>4</sup> We avoid using the term internal rate of return (IRR) since the internal rate of return for the IOC could be different from the rate of return on this project from the IOC perspective. In fact, during the contract negotiations, NIOC and the IOC must agree on a rate of return for the IOC based on a cash flow similar to the one we design in this study based on Soroosh and Nowrooz buy-back service contract. Such a cash flow produces a rate of return that might be different from the IOC's true internal rate of return.

<sup>5</sup> We do not consider other risks including geology, geopolitical factors, sanctions, domestic economic and political instability, and inflation/recession related effects.

A comparison of our contractual and actual cash flow models of the Soroosh and Nowrooz buy-back service contract reveals that Shell ended up with an actual rate of return which is significantly lower than the contractual rate of return. This finding clearly suggests that the IOC may face high degrees of risk in a buy-back service contract. In addition, we find that even though all the risk factors we considered are capable of reducing the IOC's actual rate of return, a capital cost overrun has the largest potential effect.

Sensitivity analysis based on the change of one factor may not be enough to determine the importance of economic factors. However, by gauging the relative effects of changes in the contract parameters on the IOC's actual rate of return, we are able to identify the degree of each risk factors' potential effect in terms of reducing the IOCs' rate of return.

In addition, the framework that we have designed to study these effects could be used to do scenario analysis for a combination of risk factors as well. In fact, we use our framework and methodology to do the scenario analysis based on the realization of all the relevant factors. This way we avoid choosing scenarios arbitrarily. We also study the effect of a combination of three factors including the capital cost overall, status of bank charges during the delay period, and finally proportional increase of the remuneration in accordance to capital cost overrun.

Furthermore, our methodology is an important contribution to the literature on Iran's buy-back service contracts. Our main contribution is to reemphasize on the potential effects of capital cost overrun, in contrast to existing literature's view that delay and oil price are the most important risk factors.

The remainder of this paper is structured as follows. Section 2 describes our methodology in analyzing the risk factors and rate of return in three sub-sections. Sub-section 2.1 discusses the modeling of Soroosh and Nowrooz contractual and actual cash flow followed by these models' contractual and actual ROR results. Sub-section 2.2 examines each risk factor's ROR effect. Sub-section 2.3 illustrates our proposed risk-sharing cash flow modeling and the potential ROR effects of such modification in a buy-back service contract. Section 3 concludes.

## 2. Model and results

### 2.1. Contractual and actual ROR comparison

To analyze the rate of return and risk factors faced by an IOC in a buy-back service contract, we model Shell Exploration's contractual and actual cash flow in its Soroosh and Nowrooz buy-back service contract as a case study. Based on our models, we compare Shell's contractual and actual rate of return in this contract in order to examine the difference between what Shell agreed to contractually and what the company actually ended up with in terms of the rate of return. The rate of return is mathematically the rate that gives a net present value (NPV) of zero dollars in the cash flow.

We focus on the rate of return in our analysis for two reasons. First, in the buy-back service contract, the rate of return serves as the main contract parameter since the NIOC and the IOC need to agree on a ceiling for the rate of return for the IOC.<sup>6</sup> Second, examining the IOC performance in the contract using other indices such as the net present value requires inputting the discount rate in the net present value formula.<sup>7</sup> Determining an appropriate discount rate, however, requires additional assumptions about the IOC's expected return on competing

<sup>6</sup> That means that the rate of return cannot exceed the contractual or targeted value. However, it can be lower.

<sup>7</sup> In showing the effects of the delay as a risk factor, van Groenendaal and Mazraati (2006) report the IOC's net present value for a 10% discount rate as well as the return on invested capital as the division of sum of the remuneration and bank charges by the capital cost.

projects, the IOC's perception of the inflation rate in 1999, and the IOC's cost of capital. By analyzing the rate of return rather than the NPV, our approach allows us to avoid making such assumptions about the IOC's internal discount rate. This is because our methodology in measuring the effects of each risk factor is based on comparing the rates of return that arise from different values of each risk factor with the contractual ROR that we calculate.

In general, a buy-back service contract cash flow in its basic contractual form<sup>8</sup> has three main sections: expenditure (IOC cash out), revenue (payable to the IOC), and repayment (IOC cash in). The expenditure part of the cash flow has three main sections: capital cost, non-capital cost, and bank charges. The revenue section of the cash flow consists of four elements: a contractual oil price; contractual production levels through time; operating and maintenance cost; and 60% of the maximum possible amount payable to the IOC in each period. The repayment section includes total capital cost, compounded interest, total owed to the IOC, remuneration, and the IOC's contractual rate of return. The above mentioned three sections of the cash flow shape the structure of our buy-back service contract cash flow through the following net present value formula from the perspective of the IOC ( $NPV_{IOC}$ ) as introduced by van Groenendaal and Mazraati (2006) and also discussed by Ghandi and Lin (2012):

$$NPV_{IOC} = \sum_{i=0}^T \frac{-(Capex)_i}{(1+r_{IOC})^i} + \sum_{i=T+1}^I \frac{(BankCharges)_i + (Remuneration)_i + (Repayment)_i}{(1+r_{IOC})^i} = 0, \quad (1)$$

where *Capex* stands for capital expenditures; *Bank Charges* represent the cost of borrowing by the NIOC; *Remuneration* corresponds to the amount that is allocated to the IOC as rewards for carrying out the project scope successfully; *Repayment* or the entitlement is the IOC's payback in each period that is in the form of crude based on realized actual oil price; and finally  $r_{IOC}$  refers to IOC targeted rate of return in the contract.

The net present value formula from the IOC perspective ( $NPV_{IOC}$ ) is equalized to zero in order to set the rate of return and remuneration for the IOC.

In a buy-back service contract, the IOC has also a second rate of return: the actual rate of return that is realized based on the actual cash flow. The actual cash flow<sup>9</sup> accounts for the additional non-recoverable capital costs, delays in construction, some other configurations about bank charges, actual oil prices, production, and the LIBOR. As a result, the IOC's actual rate of return could be substantially different from the contractual ROR.

Our contractual cash flow model suggests that Shell signed the contract with a rate of return of around 14%. However, our actual cash flow model reveals that Shell ended up with an actual rate of return below 1%, which is significantly lower than the contractual rate of return.

## 2.2. Risk analysis

Based on our models of cash flow, we also analyze the buy-back contract specific risk factors that may contribute to a reduction in the IOC's rate of return (ROR). These risk factors include: capital cost, the time profile for capital expenditures, operating and maintenance cost,

<sup>8</sup> The basic idea for the contractual cash flow is to mimic the real Soroosh and Nowrooz buy-back service contract cash flow. However, since we do not have access to the real one, we chose the components of the contractual cash flow in such a way to be as close as possible to the terms of the contract.

<sup>9</sup> In this paper, since the payback to the IOC has ended in 2009–2010, we are able to capture Shell's actual rate of return by setting up the cash flow based on 2009 realized values.

oil price fluctuations, delay in construction, reduction in the oil price, the contractual production level, the LIBOR, and finally the remuneration not being realized. Our analysis of the potential effects of the risk factors enables us to determine whether the IOC faces a high degree of risk in buy-back service contracts. Details of our model, data, and parameters are provided in Appendix A to Appendix D.

### 2.2.1. Capital cost

In order to show the effects of changes in the capital cost level on the IOC's rate of return, we define five scenarios: 50% lower, 20% lower, 20% higher, and 50% higher capital cost level compared to the contractual level as well as a scenario in which the capital cost is at the actual level (which was 48% higher than the contractual level). We assume that the changes in the capital cost level happen in the contractual development period with no extended period. Moreover, for the three scenarios with additional capital cost, we assume that the additional capital cost and the associated bank charges are non-recoverable by the IOC. For all the five scenarios, the remuneration remains constant.<sup>10</sup>

Fig. 1 represents the effects of capital cost on the rate of return. Increases of 20% and 50% in the capital cost will decrease the ROR from a contractual rate of return of 14.44% to a rate of return of 5.40% and 0.24%, respectively. By itself, the realized actual level of capital cost can decrease the ROR from 14.44% to 0.52%. Therefore, the capital cost is an important risk factor in a buy-back service contract.

Interestingly, even though in the contract Shell could not benefit from a reduction in the capital cost, our model shows that 20% and 50% decreases in the capital cost level could increase the rate of return to 16.39% and 21.47%, respectively.<sup>11</sup> This suggests that a capital cost reduction had the potential to increase the ROR. The NIOC could therefore consider the option of letting the IOC benefit from a capital cost reduction, as a reward for keeping costs lower than the costs specified in the contract. The same percentage reduction in the level of capital cost, compared to same percentage increase, has smaller absolute effects on the rate of return.

### 2.2.2. Time profile for capital expenditures

To show the effects of the time profile for capital expenditures on the rate of return, we define eight different time profiles for capital expenditures, as summarized in Table B.1 in Appendix B, and we report their resulting rates of return holding all else constant.

Fig. 2 presents the different capital expenditure time profiles and their associated rates of return, which suggest that changes in the time profile for capital expenditures could affect the IOC's rate of return. Therefore, the time profile for capital expenditures is a risk factor.

Moreover, as shown on the left-hand side of Fig. 2, the capital cost levels for the development period and for the extended period are the same for time profile 1 as they are for time profile 2. However, in time profile 1, the spending happens in the first year of each period while in time profile 2, the spending spreads equally in the years of each period. Comparing these two time profiles, the IOC will benefit from a higher ROR if it spreads out the capital cost.

The above result and that of a comparison of time profiles 4 and 7, which represent two extreme and unlikely possibilities, suggest that the IOC benefits most by postponing the spending towards the later years of development.

However, it may not be feasible to spend all the capital cost in one year at the beginning or at the end of the development and extended periods. As a result, a likely time profile that we assume for our contractual and actual models of cash flows relies on paying equal

<sup>10</sup> We analyze the effect of the possibility of a proportionate increase in the remuneration in accordance with an increase in capital cost in Section 2.3.

<sup>11</sup> This is mostly due to the lower IOC cash-out (capital cost level) as well as the assumption that in case of capital cost reduction, remuneration will still be fixed at the contractual level.

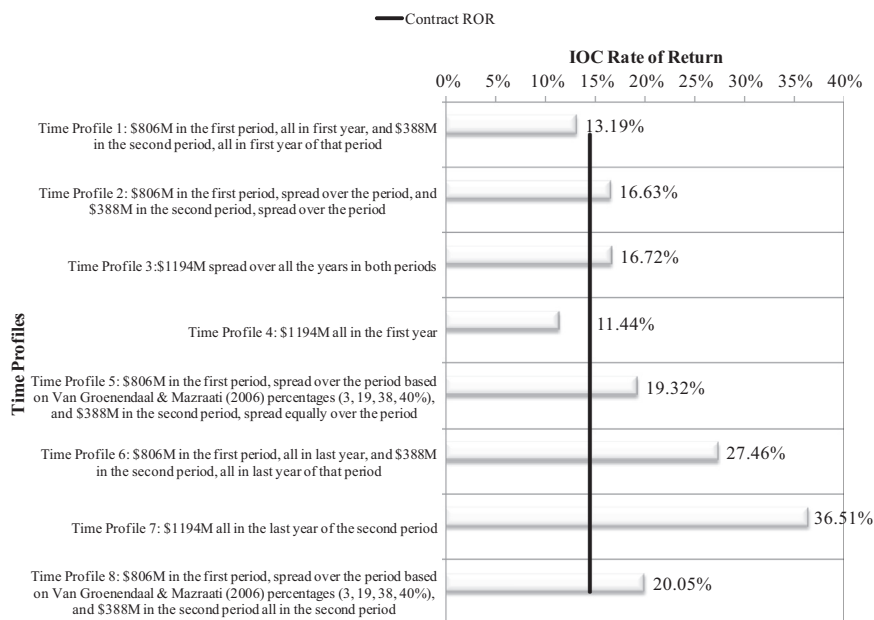


Fig. 2. The effects of the time profile for capital expenditures on the IOC's rate of return.

percentages of the capital cost in each year.<sup>12</sup> This corresponds to time profile 2.

### 2.2.3. Operating and maintenance cost

We investigate the effects of operating and maintenance cost on the ROR in two groups of scenarios: fixed and fluctuating cost.<sup>13</sup> A fixed operating and maintenance cost is considered since it is likely that the NIOC and IOC would consider a fixed operating and maintenance cost in a real cash flow. However, a wrong fixed cost estimate could affect the IOC's ROR. Therefore, in our fixed group of scenarios, we try a range of operating and maintenance cost from 0.35 to 3.73 dollars/barrel. We find that higher operating and maintenance cost will decrease the IOC's rate of return. But the degree of the effect on the rate of return is not large. A fluctuating operating and maintenance cost is also considered since in reality the cost may fluctuate, which could affect the ROR. Our fluctuating group of scenarios is designed to investigate all possible fluctuating cost trends and their effects on the ROR. The rate of return of our four fluctuating scenarios are all close to each other, and that reinforces that in this contract fluctuating operating and maintenance cost is not a source of risk for the IOC. Fig. 3 shows the scenarios and their associated rates of return.<sup>14</sup>

<sup>12</sup> We use equal percentages of capital cost in each year in order to avoid any arbitrary choice for the cash flow of Soroosh and Nowrooz buy-back service contract, and since it yields intermediate rate of return compared to other options. This means that in our contractual cash flow, we spread the contractual capital cost equally to the contractual years of the contract. For the actual cash flow, we will have two separate periods with two different percentages. In the first period (contractual), we spread the contractual capital cost equally while for the second period, we do the same with the additional capital cost in the extended development period.

<sup>13</sup> In the Appendix, we first discuss our methodology for calculating fixed operating and maintenance cost for four cases. We then use the costs calculated for these four cases to define five scenarios to examine different constant cost levels' effects on the rate of return. To do that, in our four cases and based on the literature, we find a range for the operating and maintenance cost. Then, by knowing the lower and higher bound, we select the other three operating and maintenance costs from within this range in an evenly spaced manner. In the next step, we define four scenarios, which yield fluctuating cost trends.

<sup>14</sup> Another consideration in the operating and maintenance cost scenarios regards constant versus current dollars. In the operating and maintenance cost tables and scenarios, whenever it was necessary, we convert the current dollars to 1999 dollars in order to be consistent with the contractual cash flow. For the Group one scenarios, we do not have any conversion since in this group of scenarios, the goal was to find the upper and lower bounds for the operating and maintenance cost levels. And even for the EIA

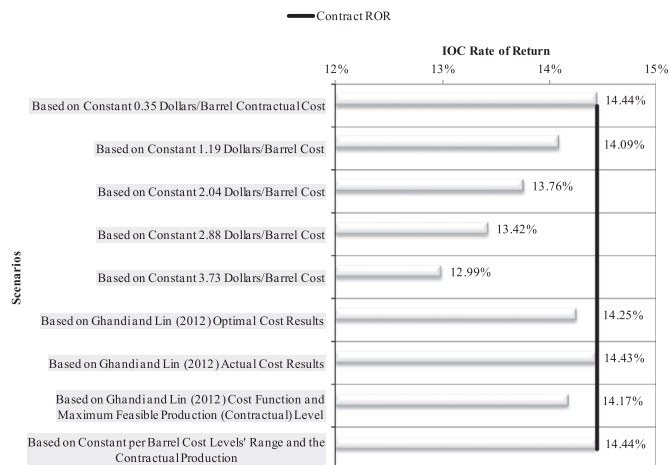


Fig. 3. The effects of operating and maintenance cost on the IOC's rate of return.

### 2.2.4. Delay in construction

While a construction delay in a complicated oil development project is sometimes unavoidable, the IOC may face a great deal of risk if it turns out that the IOC is responsible for the delay. Delay can pose a risk through reducing the IOC's rate of return in two ways. First, a delay in construction could be attributed to delay in reaching the contractual production, which affects the revenue of the fields. Lower than expected revenue will also affect the maximum payable amount to the IOC that reduces the IOC's overall rate of return. In other words, the repayments are contingent upon a certain production level starting in a certain year. Not reaching that production level for any reason, including delay in construction, will disrupt the repayments to the IOC. A second way in which delay can reduce the ROR, as suggested by van Groenendaal and Mazraati (2006), is that if it turns out that the IOC is unable to complete the scope of the contract on time, then the IOC would bear the bank charges for the period of delay. And that

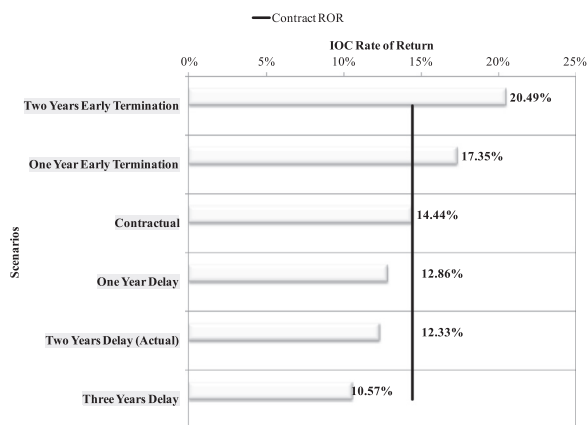
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based level, which is based on 1996 dollars, we just use the same values as reported by the EIA. In Group two, for scenarios 6, 7, and 8, we convert the cost results to 1999 dollars. Scenario 9 has no conversion neither since it is based on constant cost level scenarios.



**Table 1**  
The effects of delay in construction on the IOC's rate of return.

Scenario		Two Years Early Termination	One Year Early Termination	Contractual	One Year Delay	Two Years Delay (Actual)	Three Years Delay
Main Differences of the Scenarios	Production Starts	2000	2001	2002	2002	2002	2002
	Development Period Ends	2000	2001	2002	2003	2004	2005
	Remuneration Starts	2002	2004	2005	2005	2006	2007
<b>Delay Effects on Rate of Return</b>		<b>20.49%</b>	<b>17.35%</b>	<b>14.44%</b>	<b>12.86%</b>	<b>12.33%</b>	<b>10.57%</b>



**Fig. 4.** The effects of delay in construction on the IOC's rate of return.

subsequently reduces the rate of return as well.

In order to study the delay parameter as a risk factor, we compare the contractual rate of return with five scenarios' rate of return in which the contract is delayed or expedited for one to three years. Table 1 and Fig. 4 present these six scenarios and their associated rates of return. In the delay scenarios, a delay means an extension of the development period,<sup>15</sup> and we assume that the delay is the IOC's fault.<sup>16</sup> As a result, in the delay period, the bank charges should be covered by the IOC.

As shown in Table 1 and Fig. 4, one, two, and three years' delay in the construction could decrease the rate of return to 12.86%, 12.33%, and 10.57%, respectively, compared to a 14.44% contractual rate of return.

On the other hand, even though the IOC in a buy-back service contract cannot benefit from finishing the project earlier than scheduled, our two such scenarios suggest that by expediting the development period for one to two years, the rate of return could increase to 17.35–20.49% compared to the contractual level of 14.44%.

### 2.2.5. Oil price, production, and LIBOR

As risk factors, the oil price, production profile, and the LIBOR all share some common features, and we use a similar methodology in studying their effects on the IOC's rate of return. In general, the

<sup>15</sup> Even though one of the fields reached early production in 2002, the contract faced delay mostly due to the extension of the development period. Therefore, in the delay scenarios, we keep production the same as in the contract, and we only change the end of the development period and the start of remuneration payments. For the capital cost, we assume that it does not change, but the percentage is changing in accordance with the total years of development in each scenario. This way, in each scenario and in each year of development, the capital cost spending is equal to that of the other years in that scenario.

<sup>16</sup> This means that the IOC should bear the extra bank charges of this period. In the case of promptness of the IOC for one or two years in finishing the development period, we just reschedule the repayments accordingly. While the disruption in the IOC's repayments due to the delay is an unavoidable risk for the IOC, the NIOC could cover the bank charges of the delay period. We discuss the possibility of such a modification in the contract in Section 2.3.

changes in the rate of return through these three parameters occur in two different ways: through the change in the level of the variables as well as through the timing of those changes. Therefore, we investigate the effects of the changes in the trend of each of these risk factors separately in addition to the effect of each of the risk factors' actual trend. In the case of the Soroosh and Nowrooz buy-back service contract, we find each of these three risk factors have an effect on the IOC's rate of return. However, when comparing the effects of the actual trend of oil price, production and LIBOR on the IOC's ROR, we find the actual oil price effect has the smallest effect in terms of reducing the IOC's rate of return (resulting in a ROR of 14.37%) compared to the effects of the actual production (resulting in an ROR of 12.73%) and of the actual LIBOR (resulting in an ROR of 12.72%).<sup>17</sup>

### 2.2.6. Remuneration not being realized

The realization of the remuneration in the buy-back service contract is contingent upon successful conclusion of development and the handing over of the fields to the NIOC. This implies that if for any reason the IOC could not achieve the contractual objectives, there is the possibility that the remuneration may not be paid. Based on our analysis, we find that without remuneration, the rate of return will reach 6% in comparison with around the 14% contractual rate of return.

### 2.2.7. Contribution of the actual level of each of the risk factors to the total potential decrease in the ROR

In order to see the contribution of the actual level of each risk factor to the total potential reduction in the actual ROR, we measure the effects of the actual levels of each of the risk factors holding everything else constant using our contractual cash flow model. The results are presented in Table 2 and Fig. 5. Overall we find that capital cost has the largest potential effect with a 71.2% contribution to the total potential ROR reduction.<sup>18</sup>

### 2.2.8. Risk-sharing cash flow

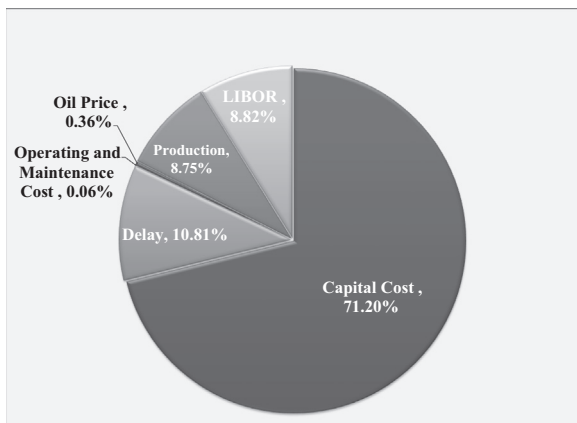
Based on our analysis of Shell's Soroosh and Nowrooz buy-back service contract as well as our personal interactions with the NIOC staff, we find that Shell's actual rate of return is significantly lower than its contractual ROR. This suggests that there are potentially high risks involved in buy-back service contracts. The difference between Shell's actual and contractual rate of return also represents uncertainty, which may prevent many IOCs from cooperating with the NIOC through the buy-back framework. In this paper we look at contractual design issues and argue that even in the buy-back framework there are ways to alleviate the degrees of risk for the IOCs. To this end, we propose a risk-

<sup>17</sup> We provide a more detailed discussion of these three risk factors' effects on the IOC's ROR in Appendix.

<sup>18</sup> It is important to remember that in the actual ROR calculation, a combination of more than one risk factor could be in effect. Studying the effects of such combinations of risk factors on the rate of return is out of scope of this paper, since we only look at each risk factor solely in order to determine the most important ones that could be addressed in policy reforms and suggestions of our work. However, analyzing the combination effects of Iran's buy-back service contract risk factors is another important step for future studies.

**Table 2**  
The effects of the actual levels of the risk factors on the IOC's rate of return.

Actual Risk Factor	Percentage Points Change with Respect to Contractual ROR	Contribution of Actual Level of Risk Factor to Total Potential Change in ROR
Capital Cost	-13.92%	71.20%
Delay	-2.12%	10.81%
Operating and Maintenance Cost	-0.01%	0.06%
Oil Price	-0.07%	0.36%
Production	-1.71%	8.75%
LIBOR	-1.73%	8.82%



**Fig. 5.** Contribution of actual levels of risk factors to total potential change in ROR.

sharing cash flow modeling in which the NIOC shares more risks with the IOC. Fig. 6 presents our risk-sharing scenarios and their rate of returns. For a risk-sharing scenario, we have two distinct periods of development. In addition, we consider two distinct possibilities for

each of three variables.

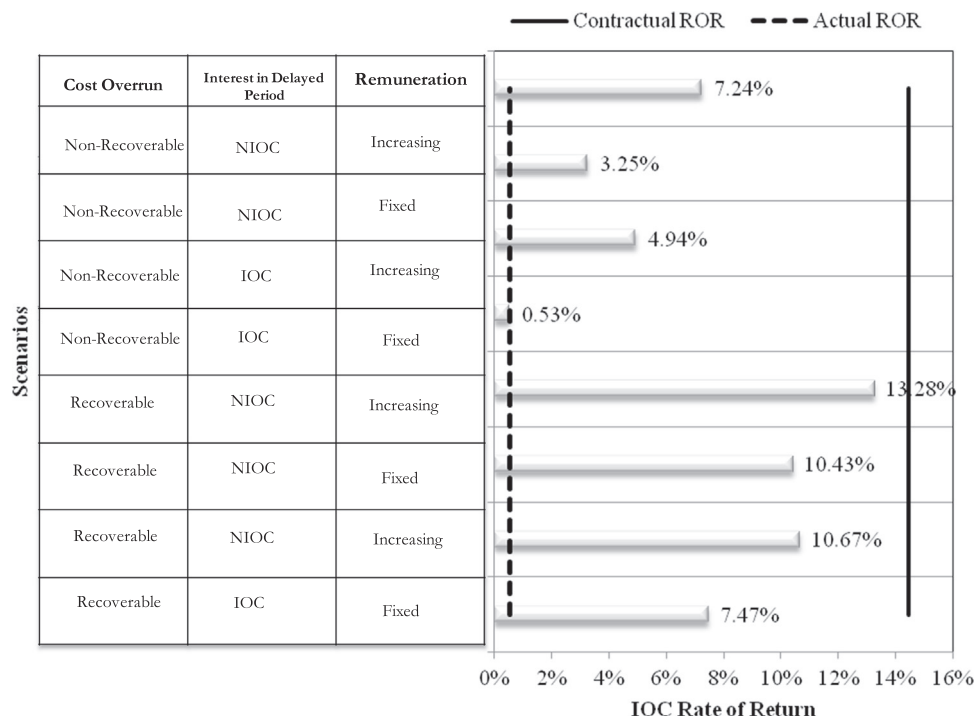
The first variable is capital cost overrun, which was not covered by the NIOC in the Soroosh and Nowrooz buy-back service contract. A possible modification in order to reduce the IOC's risk is for the NIOC to cover the additional cost. Therefore, in the risk-sharing cash flow, we could consider the two possibilities of the cost overrun being covered by the NIOC or not.

The second variable regards bank charges in the case of a delay in construction. Based on our personal communication with the NIOC staff, it was the case for Soroosh and Nowrooz that Shell covered the bank charges in the extended development period since Shell was responsible for the delay. That subsequently decreased Shell's rate of return on this contract. As a result, in a risk-sharing framework, we consider two possibilities of whether the NIOC covers the bank charges in the extended period or not.

The third variable is the remuneration in the case of cost overrun. In general, remuneration is fixed at about 60% of the contractual capital cost (van Groenendaal and Mazraati, 2006). In Soroosh and Nowrooz buy-back service contract, 60% of the contractual capital cost yields a fixed remuneration of \$450 million. However, in the case of a capital cost overrun, the current buy-back framework does not allow any changes in the remuneration. As a modification, we could consider a situation that the remuneration increases proportionally with any increase in the actual capital cost.

The different possible combinations of different values of these three variables allow us to define 8 types of risk-sharing cash flow in which the NIOC and the IOC share, to some extent, the risk due to the cost overrun or delay by increasing the IOC's ROR.

The rates of return for the different risk-sharing scenarios are presented in Fig. 6. The scenario in which the cost overrun is non-recoverable, the IOC pays the interest during the delayed period and a fixed remuneration depicts the actual cash flow of Soroosh and Nowrooz. The rest of the scenarios could be used by the NIOC to incentivize the IOC to participate in buy-back service contracts by reducing the risk and allowing changes in the rate of return in some special cases. In particular, regarding the capital cost, among the three parameters listed, if the NIOC just covers the additional cost, Shell could have reached a more acceptable rate of return of 7.47% compared



**Fig. 6.** Rates of return from risk-sharing scenarios.

to the low level of 0.53%. A risk-sharing framework in which the NIOC was covering the additional cost, bearing the interest in the delay period and paying a fixed remuneration would have let the IOC to reach a 10.43% rate of return. If the NIOC let the remuneration increase proportionally with the capital cost increase, bore the interest of the delay period and covered the additional cost, the IOC could have reached a 13.28% rate of return. This level is very close to the contractual level. Therefore, it is indeed possible to follow a more flexible framework which minimizes the risk to the IOC of getting a rate of return lower than its contractual rate of return.

### 3. Conclusion and policy implications

Shell Exploration's low actual rate of return suggests that the IOC in a buy-back service contract may face high degrees of risk. Through our detailed analysis of buy-back specific risk factors and rates of return, we show that each of the risk factors we considered has the potential of reducing the IOC's rate of return. However, among them, we identify capital cost overrun as the most important contributor in reducing the IOC's rate of return.

The finding on capital cost effects is significant for at least two reasons. The first reason is that for the first time and in contrast to the existing literature on buy-back service contracts' attention on the delay and the oil price, this finding brings the capital cost issue into the center of discussion regarding these contracts. This finding is important for future analyses of buy-back service contracts and for a better understanding of the behavioral changes and decisions of the IOCs and the NIOC. In particular, the NIOC's recent decision to have an open capital cost policy is an example of such a behavioral change. Through this new policy, the IOC<sup>19</sup> is allowed to postpone its decision on the final capital cost ceiling up to two years after the start of the project.<sup>20</sup> This way, the NIOC would be able to minimize the chances of a capital cost overrun, and it could keep the ROR from decreasing. In other words, this policy eventually should reduce the degree of risk faced by IOCs in new buy-back service contracts. This example also explains well our findings on capital cost, and it confirms the accuracy of our rate of return and risk sensitivity analyses.

The second reason that our finding on the capital cost effects is significant is that in other types of oil service contracts, including Iraq's technical service contract, the capital cost overrun is not necessarily the most important risk factor. In other words, since the situation with the capital cost overrun as a risk factor is not common in other types of service contracts, showing quantitatively the potential effects of such an overrun on Iran's buy-back service contract is a noteworthy endeavor.

Shell's low actual ROR implies a potential threat to the IOC's presence in Iran's oil and natural gas industry through the buy-back service contract framework. However, our model of risk-sharing cash flow, as shown in Fig. 6, suggests that there is a potential for modifying the contracts to better share the risk, while still remaining in the framework of buy-back service contract. By modifying the contracts to share the risk, the IOC could face an actual ROR closer to the contractual ROR even if the contract faces cost overrun or delay, and yet still keep the actual ROR from exceeding the maximum contractual ROR the NIOC is willing to give. If the NIOC wants to continue using the buy-back framework, such modification is vital in order to avoid deterrence of the IOCs from large investments in Iran's oil and natural gas industry. Showing the potential of improvement within the framework of a buy-back is also important since our methodology and findings could be referenced within the NIOC at different managerial levels in order to improve the contracts. Our risk-sharing cash flow

methodology also opens the door for other types of modifications in buy-back service contracts. In what follows three such modifications are discussed.

As the first modification, the NIOC could consider a limited open ROR policy in the buy-back service contracts. The NIOC could think of this as rewarding the IOCs who fulfill certain objectives in favor of the project. For example, since we have argued that a delay in construction is a risk factor for the IOC, in cases in which the IOC finishes the job sooner than it was expected, as shown in Fig. 6, the IOC's ROR could be increased. Therefore, in such a situation, the NIOC should allow the IOC to benefit from the higher ROR as a reward. This way, we may even go further and propose a new name for such contracts, such as a risk and rewards contract, or a risk and rewards buy-back service contract.

Another modification could be to put a lower bound on the IOC's ROR in these contracts. In order to keep the ROR above certain minimum level, the NIOC and the IOC could agree on detailed procedures to follow in cases of any or all of the risk factors take effect. Such a design of the contract might require assessing the optimal degree of risk-sharing between the NIOC and the IOC and in accordance with determining the maximum and minimum contractual ROR. It is also important to remember that the risk-sharing framework in development versus exploration and development contracts might not necessarily be the same.

As a third modification, since there is a wide range of possible modifications to buy-back service contracts, NIOC could offer different types of risk-sharing contracts to different IOCs. That is important because it is the case that not all the IOCs are the same regarding their ability of carrying out complicated oil and natural gas exploration and development projects. In addition, since the NIOC uses the buy-back framework for exploration projects, it can offer a risk-sharing contract as a reward for the IOCs that carry the exploration successfully.

Our estimate of Shell's contractual rate of return, at around 14%, is indeed in the approximate range of expected rate of return in other service type contracts in Iran and Iraq, as listed in Table 3. However, our estimate of Shell's actual rate of return in this contract, below 1%, is not only very low compared to the contractual ROR, it might also be even lower than the minimum expected rate of return that IOCs generally would be willing to accept.<sup>21</sup>

Finally, we should emphasize that the current financial sanctions against Iran have significantly affected the future of international oil companies in Iran. In other words, discussing the IOCs and National Iranian Oil Company's preferred financial arrangements in developing oil and natural gas in Iran might seem irrelevant these days. In general, we believe sanctions are part of a broader spectrum of upstream oil and natural gas risks. However, we do not consider them as risk factors in this study for two reasons. First, this paper is a technical study of risk factors based on the terms of a buy-back service contract. Therefore, other factors such as sanctions or political instability of Iran or the region are not the focus of the study even though they are very important. Second, this contract was signed in 1999 during a reformist administration in Iran. At the time, there were various mutual interests between portions of the Iranian government and the NIOC on one hand and the IOCs and Western countries on the other hand to promote the cooperation at different levels including development of Iranian oil and natural gas fields. Therefore, and in order to have a more time relevant rate of return and risk sensitivity analysis, we only focus on buy-back specific risk factors even though some of the risk factors, including oil price, production and LIBOR do not contribute much in overall IOC rate of return reduction.

<sup>19</sup> Sinopec International Petroleum E & P Corporation in this case.

<sup>20</sup> Personal communications with NIOC staff, September 2009.

<sup>21</sup> Personal communications with Chevron Corporate Strategic Planning staff, March 2011.

**Table 3**  
International oil companies' expected rate of return in Iran and Iraq.

Country	Type of Contract	International Oil Companies' Expected Rate of Return	Source
Iran	Buy-Back Service Contract	12–15%	van Groenendaal and Mazraati (2006)
Iran	Buy-Back Service Contract	16%	Shiravi and Ebrahimi (2006)
Iraq	Technical Service Contract	12–22%	Sankey et al. (2010)

## Appendix A. Parameters and data

In this study, there are 15 parts of the contract that we considered in developing our model. These parameters include: development and extended periods, capital cost expenditures (contractual and actual), the time profile of capital expenditures, non-capital cost expenditures, operating and maintenance cost, bank charges, LIBOR (contractual and actual), production (contractual and actual), oil price (contractual and actual), and remuneration. In what follows, each of these parameters is discussed.

The contractual development period in Soroosh and Nowrooz buy-back service contract was from 1999 until 2002. However, the fields were handed over in 2005 (Middle East Economic Survey, 2005). Therefore, we consider the years 2003 and 2004 as the extended development period.

The capital cost is the IOC's investment in the development period to fund the expenditures of developing the fields of the contract (Shiravi and Ebrahimi, 2006). The capital cost is one of the most important, and sometimes controversial, parts of a buy-back service contract cash flow. It might be controversial because in the negotiations over the cash flow of the contract, the NIOC has to agree on the capital cost ceiling before the start of the project. On the other hand, since the IOC might not have a perfect assessment of the fields before start of the project, this requirement probably makes the capital cost the number one risk factor in these contracts. We therefore give particular attention to all aspects of the capital cost including the contractual and actual capital cost levels, the time profile for capital expenditures in the years of the contractual and extended development periods, and whether or not the cost overrun was recoverable by Shell.

For the capital cost, we need the contractual and actual levels of capital cost as well as the time profile for capital expenditures in each year of development and extended periods. As summarized in Table A.1 below, the contractual capital cost level varies from \$799 M<sup>22</sup> to \$806 M based on the literature and commercial sources. We choose the \$806 M as the contractual capital cost in our cash flow, due to the reliability of the source of this value (OIEC, 2002).<sup>23</sup>

Table A.1 also includes a range of reported values for the actual capital cost between \$906 M to \$1400 M. In this paper, we choose to take the \$1400 M (higher end) as the actual capital cost level since this value was taken from more reliable sources including our personal communication with NIOC staff. The \$1400 M total actual cost is based on announcements in 2010. However, since the fields were handed over in 2005, it is reasonable to assume that the \$1400 M is based on 2005 dollars. Therefore, in order to be able to compare the actual and contractual cash flows, we convert that to 1999 real dollars which means that \$1400 M in 2005 dollars is equivalent to \$1194 M in 1999 dollars.

Besides the total capital cost ceiling, the NIOC and IOC have to agree on the IOC's time profile for capital expenditures during the development period. The time profile for capital expenditures for Soroosh and Nowrooz buy-back service contract were not available. Therefore, in order to model the capital expenditure profile, we have to assume the time profile for capital expenditures of the contractual and extended development periods. We also assume that the IOC is not strategically delaying its capital cost expenditure in order to receive a higher rate of return.

In buy-back service contracts, the non-capital cost includes taxes, social security fixed charges, custom import duties and all other levies required by the Iranian laws (Shiravi and Ebrahimi, 2006). Non-capital costs in these contracts are between 5% and 15% of the capital cost.<sup>24</sup> In our study, we consider 10%, which is the mid-value of the range. Since non-capital costs include taxes, we do not have a separate section for tax. This assumption is in accordance with what van Groenendaal and Mazraati (2006) argue about tax considerations in a buy-back service contract cash flow. They provide the Net Present Value formulas from the perspective of the IOC and the NIOC separately, and neither formula includes tax parameters. For the IOC, they emphasize the fact that the remuneration is not taxable. Moreover, for the NIOC, they assert that the taxes that the NIOC should pay as a government entity is in fact reallocating revenue to other government entities and therefore, that should not affect the NIOC Net Present Value in this contract. However, any tax consideration might decrease the IOC's upper bound repayment, which is 60% of the fields' profit. That is because in reality, the NIOC might be taxed on its profit from the fields, which subsequently decrease the upper bound for the repayment to the IOC. In case the NIOC is being taxed and in order to make sure that the taxes are not affecting the IOC's rate of return, we assume that the amount of tax is reduced from the NIOC's 40% of the net profit that it keeps for itself. In other words, this assumption implies that taxes do not affect the upper bound revenue of the IOC repayments.

Another important parameter of the contract is the operating and maintenance cost, which refers to the cost of crude oil production from Soroosh and Nowrooz starting 2002. As mentioned in the above, the period from 2002 until 2004 is actually part of the development and extended periods. In order to calculate net profit in this period, we follow Shiravi and Ebrahimi's (2006) definition of the operating and maintenance cost as one of the four categories of cost during the development period. Having the operating and maintenance cost to calculate the net profit implicitly suggests that there is no bank charges on this cost, since it is assumed that the operating and maintenance cost is cleared by the fields' next period revenue. Since we did not have access to the contractual and actual operating and maintenance cost for the Soroosh and Nowrooz buy-back service contract, we define scenarios in order to capture a wide range of possibilities. These scenarios are discussed below. Among the defined scenarios, we follow van Groenendaal and Mazraati's (2006) suggestion of annual operating and maintenance cost as 3% of total capital cost (our Scenario 2). We also use Scenario 7: Based on Ghandi and Lin (2012) actual cost results as the actual operating and maintenance cost.<sup>25</sup>

In the cash flow of a buy-back service contract, bank charges are among the parameters that are directly negotiated over. In general, bank charges are the interests on the capital cost, which include both the interest on the principal investment as well as compounded interests. In order to set-up the cash flow models in this study, we have to calculate the interest on the IOC's principal investment and the compounded interests. As

<sup>22</sup> 799 million dollars

<sup>23</sup> Even though the differences of the reported values are not high, we could justify taking the highest end of the range by assuming that \$806M was the total recoverable capital cost.

<sup>24</sup> Personal communication with NIOC staff, September 2009.

<sup>25</sup> These estimates have been converted to 1999 real dollars.



**Table A.1**

Soroosh and Nowrooz contractual and actual capital cost.

Description	Value1 (million dollars)	Value2 (million dollars)	Value3 (million dollars)	Final Chosen Value (million 2005 dollars)	Final Chosen Value (million 1999 dollars)
<b>Capital Cost (Contractual)</b>	800[1]	799[1] [2]	806 [3]	806	806
<b>Capital Cost (Actual)</b>		906 [4]	1400 [5]	1400	1194
<b>Sources</b>					
[1]	Soroosh and Nowrooz Buy-Back Service Contract (Personal communications with NIOC staff)				
[2]	Van Groenendaal, W.J., & Mazraati, M. (2006). A critical review of Iran's buyback contracts. <i>Energy Policy</i> , Volume 34, Issue 18, 3709–3718.				
[3]	Oil Industries' Engineering and Construction (OIEC). (2002). <i>Soroosh and Nowrooz</i> . Retrieved March 2011, from: <a href="http://www.oiecgroup.com/pr/projects/sor_nor.aspx">http://www.oiecgroup.com/pr/projects/sor_nor.aspx</a>				
[4]	Wolfensberger and Critchlow (2005). Shell loses \$100 M at Iran field. <i>Gulf times</i> . Retrieved March 15, 2011 from <a href="http://www.gulf-times.com/site/topics/printArticle.asp?cu_no=2 &amp; item_no=44192 &amp; version=1 &amp; template_id=48 &amp; parent_id=28">http://www.gulf-times.com/site/topics/printArticle.asp?cu_no=2 &amp; item_no=44192 &amp; version=1 &amp; template_id=48 &amp; parent_id=28</a>				
[5]	Platts Oilgram News (July 26, 2010). <i>Iran</i> . As reported from Shana News Agency. Retrieved March 16, 2011 from LexisNexis Academic.				

reported by Shiravi and Ebrahimi (2006)<sup>26</sup> and van Groenendaal and Mazraati (2006),<sup>27</sup> the interest rate in these contracts is calculated based on the London Interbank Offered Rate (LIBOR) and an additional premium. The LIBOR is an interest rate index for the global money markets. It is announced daily for 10 currencies and 15 different maturities. However, for this study, we use the historic USD LIBOR for one-month period maturity from 1999 to 2010 provided by BBA LIBOR Company.

Due to fluctuations in the LIBOR over time, we also consider LIBOR as another risk factor in this study, and we study its effects on the rate of return.<sup>28</sup> In particular, for our contractual cash flow, we use a LIBOR rate of 6%, which includes a 5.25% annual average for 1999 and a 0.75% premium. We keep this fixed for the whole periods of development and amortization. For our actual cash flow, we use the actual annual average of the LIBOR for the years 1999–2010 plus the premium.

In our contractual cash flow model, we use the contractual production profile and oil price. However, in reality, the actual production profile and oil price may deviate from the contractual levels. Therefore, in this paper, we also consider the production level and oil price as two risk factors for the rate of return.

We consider the contractual oil price in our models of cash flow at \$15/barrel fixed (van Groenendaal and Mazraati, 2006). We also need actual oil prices for 2002 (2005 for Nowrooz) until 2010. Since we do not have access to actual oil prices, we follow Ghandi and Lin's (2012) price estimates. For the years 2005–2010, we use Ghandi and Lin's (2012) 2009 perspective's price estimates, which are based on the EIA 2008 Reference case estimates in 2006 dollars.<sup>29</sup> We assume that the EIA's adjusted 2008 Reference case price levels for the years before 2008 are in fact actual prices. Since Soroosh reached the production in 2002, we also need price estimates for the years 2002–2004. For the year 2004, we use Ghandi and Lin's (2012) 2009 perspective price estimate of 2004 which is based on 2004 adjusted OPEC basket price.<sup>30</sup> For 2002 and 2003, we use Ghandi and Lin's (2012) 2004 perspective price estimates, which are based on the EIA 2003 Reference case estimates in 2001 dollars. As mentioned, based on the EIA's 2003 Reference case price projection, the price levels for 2002 and 2003 are indeed actual prices.<sup>31</sup> All conversions are based on the US CPI of the associated years.

For the contractual cash flow, we use Soroosh and Nowrooz contractual production profile based on the fields' production forecast curves. For the actual cash flow, we use the actual production profiles of the two fields until 2009.

The contractual production profiles, which we use in this paper, are complete versions of Ghandi and Lin (2012) contractual production profiles since here in this paper, the contractual production profiles also include production levels for the years before 2004. For the cash flow analysis, it is important to consider the production before 2004.<sup>32</sup> This is because in Soroosh and Nowrooz buy-back service contract, once production reaches and stays at a certain threshold, the amortization period starts. Based on the contractual production profiles, the amortization period should have been started in 2002 along with the start of production from Soroosh field. Actual production profile also suggests that the amortization did start in 2002.

Remuneration is another parameter of attention in this study. The remuneration consists of additional payments to the IOC as the reward for carrying out the project. In general, IOC and the NIOC agree on the remuneration level in association with the targeted rate of return for the IOC. Its realization in a buy-back service contract is contingent upon successful conclusion of the development and the handing over of the fields to the NIOC. Therefore, as argued by Shiravi and Ebrahimi (2006), the remuneration parameter could also be a source of risk in the buy-back service contract. There are five important considerations in our study regarding the remuneration. First, the contractual value for the remuneration is about \$450 M. Second, the remuneration fee recovery period is considered 60 months, or 5 years, and we assume the remuneration fee recovery starts after the fields reach full production. We also assume equal percentages of remuneration payments in the five years in order to avoid any arbitrary choice of percentages. Fourth, in our actual cash flow, we need to make sure that Shell has indeed received the remuneration, and since the contract reached the objective, we assume that Shell has received the remunerations in full.<sup>33</sup> Since in the contract, the two fields' cumulative contractual production should have reached the 190,000 barrels/day by 2004, we assume that remuneration payments should have started in 2005.

<sup>26</sup> Shiravi and Ebrahimi (2006) suggest a 0.75% premium.

<sup>27</sup> Van Groenendaal and Mazraati (2006) consider a 6.5% LIBOR and a 1% premium in their model of cash flow.

<sup>28</sup> Overall, in our cash flow models, we need a LIBOR rate in two separate places. First, in the expenditure part of the cash flow, at the end of each year, we calculate the total owed to the IOC, which includes the total capital invested by the end of that year plus the interest over the last year's total owed. Then, in the repayment section of the cash flow, total owed to the IOC is calculated annually, with the consideration that there is still the interest incurred on the remaining total owed to the IOC, which includes the remaining of the principal investment and compounded interest.

<sup>29</sup> The estimates have been converted to 1999 dollars.

<sup>30</sup> This estimate has also been converted from 2004 to 1999 dollars.

<sup>31</sup> 2002 and 2003 estimates based on 2001 dollars have also been converted to 1999 dollars.

<sup>32</sup> We consider 58,000 and 62,000 barrels/day cumulative contractual production for the years 2002 and 2003 respectively.

<sup>33</sup> This does not contradict the fact that Shell had to fund the non-recoverable additional capital cost beyond the contractual level.

## Appendix B. Time profile for capital expenditures

As summarized in [Table B.1](#), in our first time profile for capital expenditures, we assume that the contractual capital cost and the additional capital cost have been spent on the first year of the contractual and extended development periods respectively.

**Table B.1**  
Time profile scenarios for capital expenditures.

Time Profile	Description	Years					
		1999	2000	2001	2002	2003	2004
		<b>Capital Cost Values (Million Dollars)</b>					
1	\$806 M in the first period, all in first year, and \$388 M in the second period, all in first year of that period	806.00	0.00	0.00	0.00	388.27	0.00
2	\$806 M in the first period, spread over the period, and \$388 M in the second period, spread over the period	201.50	201.50	201.50	201.50	194.13	194.13
3	\$1194 M spread over all the years in both periods	199.04	199.04	199.04	199.04	199.04	199.04
4	\$1194 M all in the first year	1194.27	0.00	0.00	0.00	0.00	0.00
5	\$806 M in the first period, spread over the period based on <a href="#">van Groenendaal and Mazraati (2006)</a> percentages (3, 19, 38, 40%), and \$388 M in the second period, spread equally over the period	24.18	153.14	306.28	322.40	194.13	194.13
6	\$806 M in the first period, all in last year, and \$388 M in the second period, all in last year of that period	0.00	0.00	0.00	806.00	0.00	388.27
7	\$1194 M all in the last year of the second period	0.00	0.00	0.00	0.00	0.00	1194.27
8	\$806 M in the first period, spread over the period based on <a href="#">van Groenendaal and Mazraati (2006)</a> percentages (3, 19, 38, 40%), and \$388 M in the second period all in the second period	24.18	153.14	306.28	322.40	0.00	388.27
<b>Capital Cost (Contractual)</b>	\$806 M 1999 Dollars						
<b>Capital Cost Overrun (Actual)</b>	\$1194.27 M 1999 Dollars						
<b>Additional Capital Cost</b>	\$388.27 M						

In the second time profile, we assume that the spending on the contractual capital cost and the additional capital cost could be spread equally over the two periods of the contractual and extended development periods, respectively. Therefore, in this profile, we enforce two separate percentages for each of the contractual and extended development periods. For the contractual development period, we use the contractual capital cost to calculate the percentage, and for the extended period, we use the additional capital cost.

In the third time profile, we have equal percentages for all the years of development including the extended period. In order to calculate the percentages in this profile, we divide the total actual capital cost by the total years of development including the extended years.

For the fourth time profile, we assume that it is possible for the IOC to invest all the capital in the first year of the whole development including both contractual and extended periods. In this profile, we will have the actual total capital cost in the first year of the cash flow and nothing in the later years of the development periods.

For the fifth time profile, we follow [van Groenendaal and Mazraati \(2006\)](#) suggested percentages for our contractual development period. The percentages of their study were for a natural gas buy-back service contract cash flow. However, since that contract's development period is just one year longer than the Soroosh and Nowrooz development period, we use exactly the same percentages except for our last year of development which is a combination of their two last years.

Time profile six is similar to time profile one, but the contractual and additional costs are all in the last years of development and extended periods, respectively.

In time profile seven, we have all the total actual cost in the last year of the extended period.

Similar to the fifth time profile, in our eighth time profile we follow [van Groenendaal and Mazraati's \(2006\)](#) suggested percentages for our contractual development period. But in contrast to the fifth time profile, for the extended period we have all the additional cost in the last year.

## Appendix C. Operating and maintenance cost

### C.1. Group one: scenarios 1–5 (constant trend operation and maintenance cost)

#### C.1.1. Option 1: Based on contractual revenue

In this option, for each year in which there is production, we calculate gross revenue based on the contractual price of 15\$/barrel and the contractual production level of 190,000 barrel /day. Then we use 5% of this number for each year as the operating and maintenance cost for that year to calculate the net revenue (gross profit). This option results in 0.75 \$/day/barrel operating and maintenance cost.

#### C.1.2. Option 2: Based on capital cost ([van Groenendaal and Mazraati \(2006\)](#))

In this option, we assume that the annual operating and maintenance cost is about 3% of total capital cost of the project, as suggested by [van Groenendaal and Mazraati \(2006\)](#). Then we get the per barrel cost by dividing the annual operating and maintenance cost by 190,000 barrels/day contractual production. This method results in 0.35 \$/day/barrel operating and maintenance cost.

### C.1.3. Option 3: Based on optimal production models (Ghandi and Lin (2012))

In the third option, we follow Ghandi and Lin's (2012) method of calculating the operating and maintenance cost as a function of reserve remaining and production. Their Soroosh and Nowrooz calibrated cost function takes into account the stock effect, which suggests that more extraction will increase the cost of future extraction. Such consideration implies an increasing marginal cost trend.

We use this option method to get an estimate of the constant cost level and to get the fluctuating cost trend (second group of scenarios).

Ghandi and Lin's (2012) cost function has the following mathematical form:

$$C(S_0 - S_t, Q_t) = c_1 e^{c_2(S_0 - S_t)} Q_t + c_0, \quad (C.2)$$

where  $c_1=1.02899$  and  $c_2=0.00125868$ ;  $Q_t$  is the extraction rate for each period;  $c_0$  is the constant that has been calculated in accordance with Soroosh and Nowrooz fields' specifications; the initial reserves ( $S_0$ ) and reserves remaining ( $S_t$ ) are in barrels and cost is in dollars per day. However, for this part of the study, besides the total cost, we are interested in per barrel cost, which could be interpreted as the average or the marginal cost. The average cost is simply equal to the marginal cost plus the term  $c_0/Q_t$ . As it was mentioned, due to the stock effect consideration, the marginal cost should follow an increasing trend. Therefore, here, we use the marginal cost values. In order to calculate the marginal cost values we have two options. One is to use the marginal cost formula as well as reserve and production values for the marginal cost calculation. The second option, which we follow, is to use the associated cost values from the optimal production models for each field and for the reported discount rates in the Ghandi and Lin (2012) study. For that, we take the daily cost and subtract the constant value. The constant value is \$7700 and \$9100 per day for Soroosh and Nowrooz respectively. The remaining divided by the production gives us per barrel cost or marginal cost.

We use the three year/perspective versions of each of the two fields used in Ghandi and Lin (2012), which include the 1999, 2004 (2005 for Nowrooz), and 2009 year/perspective versions, for different discount rates.

Taking the total average cost over all the discount rates in each year/perspective versions for each field as well as the total per barrel cost for both fields together, we can consider \$2.06/barrel as the constant value for option three of the operating and maintenance cost. This cost level is indeed in the range of the other options' values.

### C.1.4. Option 4: Based on EIA (1996)

EIA's oil production capacity expansion cost study for the Persian Gulf region countries<sup>34</sup> (EIA, 1996) is probably the best source that includes oil production development and operating costs estimates for this region. As an important feature, this study takes into account the geographic characteristics of different plays onshore and offshore in the Persian Gulf countries rather than looking at country specific cost estimates. One of the studied plays in this report is the offshore Persian Gulf. As summarized in table below, for each play including the offshore Persian Gulf, there are three field sizes of low, mid and high that results in three types estimates of low, mid and high.

The estimates of the operating costs for each of the three scenarios consist of fixed and variable parts. For the fixed part, EIA considers 5% of the study's development cost in each play as the annual fixed operating cost. For the variable cost that depends on the field's production rate, EIA considers \$0.25 to \$1 per barrel. The cost estimates are for the peak year production for each field size, and the estimates are in 1994 dollars.

For our study, we use operating cost estimates for the Persian Gulf play since Soroosh and Nowrooz are both offshore fields in the Persian Gulf. In addition, since the two- or three- year negotiation period of the contract was before 1999, it is reasonable to use cost estimates that were published in 1996. Also in their production cost, Gao et al. (2009) have used the EIA study's variable operating and maintenance cost estimates and formulas.

Since the concern of EIA (1996) study is the oil production, there is no cost of processing the associated gas of the same fields. Among the three field sizes in EIA (1996), we choose the high case since it provides the highest cost estimates, and since Soroosh and Nowrooz's characteristics are close to this scenario's field. Among several cost indexes summarized in the above table, for our study and in order to compare with other cost options, we look at the per barrel operating cost. For the high case, the operating cost is \$1.86 per barrel. And that implies a \$3.73 per barrel cost of operating the Soroosh and Nowrooz fields together.

## C.2. Group two: scenarios 6–9 (fluctuating trend operating and maintenance cost)

In the buy-back service contract cash flow, it is the case that optimal and maintenance cost is constant in all the years of the cash flow. Group one of scenarios were to investigate the effects of different fixed cost levels on the rate of return which will show the potential risk associated with changing the cost level in the years of the cash flow.

However, in reality, it is reasonable to assume that the operating and maintenance cost trend fluctuates through time. Therefore, for the second group of scenarios, we discuss the effects of having fluctuated cost trend instead of constant trend. Overall, in this group of scenarios, we define four scenarios. And for each scenario, we use a specific method of calculating the cost trend.

### C.2.1. Scenario 6: based on Ghandi and Lin (2012) optimal cost results

Scenario 6 is based on Ghandi and Lin (2012) and their optimal production models. In their study and in three year/perspective versions, they have reported optimal production paths for different discount rates for each field. For the optimal production paths, there are also realized cost paths. Since the optimal production paths fluctuate, the realized cost fluctuates as well. In order to show these cost fluctuations' effects on the rate of return, among the optimal cost results for different discount rates and year/perspectives, we choose a cost trend with the most extreme fluctuations in the years of 2004 (2005) to 2010.<sup>35</sup> To do that we take the following steps for each field:

Step one: For each year/perspective and for each reported discount rate, we calculate the maximum variations in the cost trend of the years 2004 (2005) to 2010.

<sup>34</sup> Iran, Iraq, Kuwait, Qatar, Saudi Arabia, Abu Dhabi, and Dubai.

<sup>35</sup> These are the years of amortization with operating and maintenance cost.

Step two: For each year/perspective, we find the discount rate that yields the greatest difference between 2010 and 2004/2005 values of realized total cost.

Among these, Soroosh 2004 year/perspective's discount rate 1% yields the most extreme realized cost trend for the years of 2004–2010. Similarly, for Nowrooz, 1999 year/perspective's discount rate 2% is the one with most extreme realized cost trend.

C.2.2. Scenario 7: based on Ghandi and Lin (2012) actual cost results

Ghandi and Lin (2012) also report the actual production levels for the years 2004 (2005) to 2009 for the Soroosh and Nowrooz fields. For scenario 7, we take their cost function to calculate the realized actual cost for the actual quantities. For this, we have to make two simplifying assumptions. First, since we also need 2010 cost levels in the cash flow, we assume the same production level for 2009 and 2010 on each field. Second, since Nowrooz production starts in 2005 and we need cost level for 2004 in the cash flow, we assume the same cost level for 2004 and 2005 on Nowrooz field.

C.2.3. Scenario 8: based on Ghandi and Lin (2012) cost function and maximum feasible production (contractual) level

In this scenario, based on Ghandi and Lin's (2012) cost function, we calculate the realized cost of the contractual (maximum feasible) quantity of each field for the years of 2004–2010. We assume the same cost level for the years 2004 and 2005 in Nowrooz oil field.

C.2.4. Scenario 9: based on constant per barrel cost levels' range and the contractual production

Our first group of scenarios consists of 5 scenarios which all yield a constant operating and maintenance cost. Here in scenario 9, a fluctuating cost scenario, we use the lower and upper bound per barrel costs of the first five scenarios. We set the value of the lowest per barrel cost as the per barrel cost for each of the two fields in 2004. We also set the 2010 per barrel cost equal to the maximum per barrel cost of the five constant scenarios (scenario 5 value which is \$3.73/barrel). Then we calculate the per barrel cost level for the years in between in such a way that we end up with a linear increasing cost trend from 2004 to 2010.

Since we need the total cost for the cash flow, we simply multiply the above per barrel cost by the contractual production level for the years from 2004 to 2010. Soroosh's contractual production from 2004 to 2010 is 100,000 barrels/day. Nowrooz's production in the first few years is 90,000 barrels/day until 2008. But we assume the same level for 2009 and 2010 as well.

Appendix D. Oil price, production, and LIBOR

D.1. Oil Price

Fig. D.1 presents the oil price scenarios and their associated rates of return. The scenarios can be divided into three main groups plus an actual oil price scenario. In the first group, we use different oil price trends in all the years of amortization. We find that an oil price 20% lower than contractual in all the years has larger absolute effects in terms of reducing the IOC ROR compared to a scenario with an oil price 20% higher than contractual in all the years. In this group, we also have two paired increasing/decreasing trend scenarios with mixed results. While a simple increasing trend has slightly higher absolute effects in increasing the IOC ROR compared to a simple decreasing scenario, a scenario with an increasing trend from the beginning followed by a decreasing trend from the middle year has smaller absolute effects compared to a scenario when the decreasing trend starts from the beginning followed by an increasing trend from the middle year.

In the second group of scenarios, we have an oil price one year 20% lower or higher than the contractual level. Among these scenarios, the timing of the changes is important. In particular, we find that an oil price 20% lower or higher than contractual in the first and last year of the amortization period has no effects on the IOC ROR. However, similar changes in the middle year of the amortization could change the ROR to 14.26% (14.57%

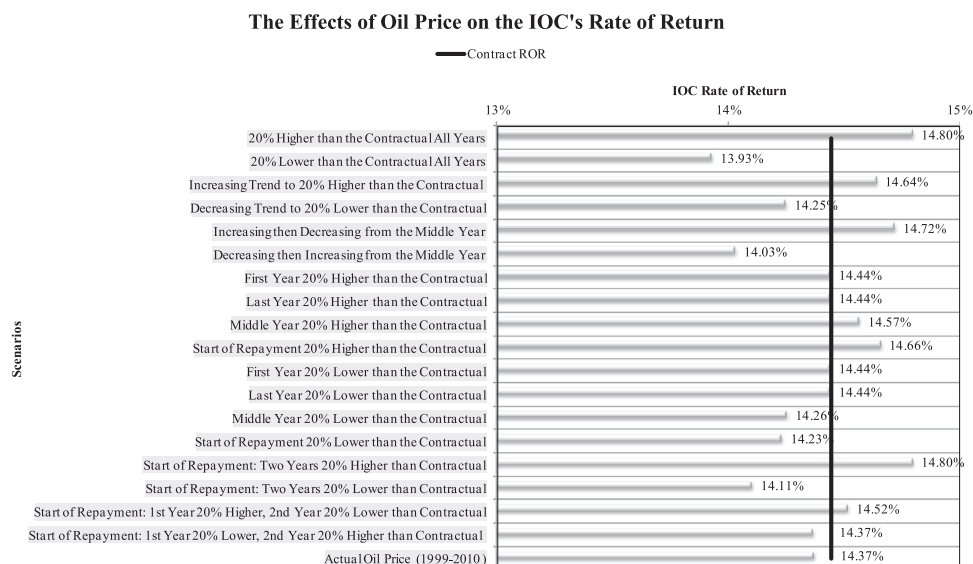


Fig. D.1. The effects of oil price on the IOC's rate of return.



The Effects of Production on the IOC's Rate of Return

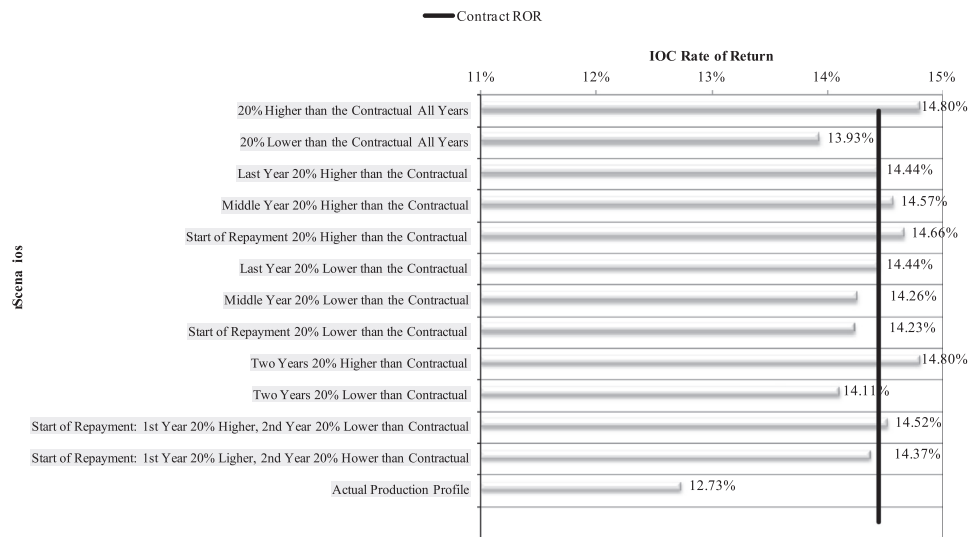


Fig. D.2. The effects of production on the IOC's rate of return.

The Effects of the LIBOR on the IOC's Rate of Return

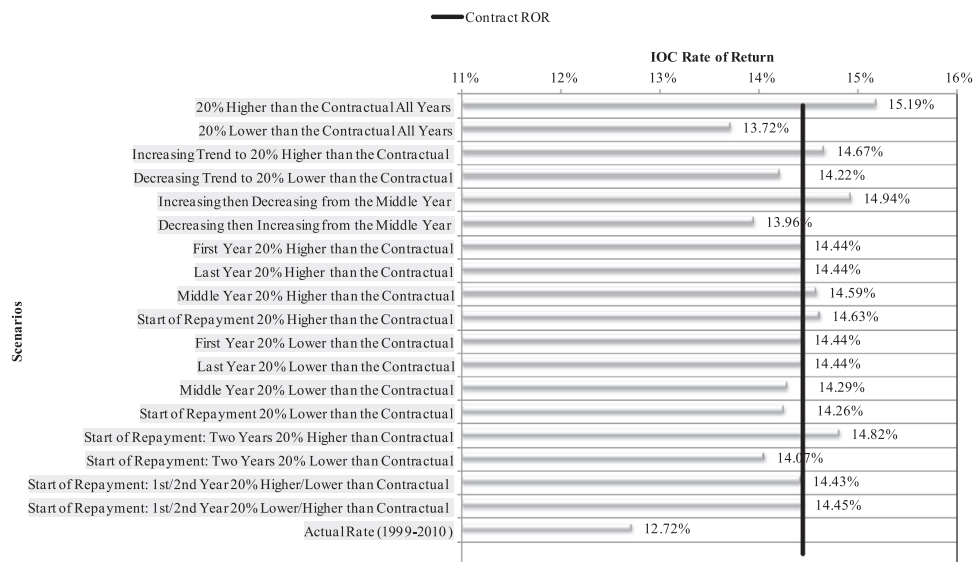


Fig. D.3. The effects of the LIBOR on the IOC's rate of return.

for higher scenario). The same way, an oil price 20% lower or higher than contractual in the year of start of repayment could reduce/increase the IOC ROR to 14.23% or 14.66%, respectively, compared to a 14.44% contractual level.

In the third group, we have an oil price 20% lower or higher than contractual in the two consecutive years with the start of the repayment. Among these scenarios, we find that a scenario with an oil price 20% higher than contractual has larger absolute effects than a scenario with an oil price 20% lower than contractual. Also, a scenario with an oil price 20% lower in the first year and 20% higher in the second year could reduce the IOC ROR to 14.37%<sup>36</sup> while a vice versa situation could increase the IOC ROR to 14.52%.

C.2. Production profile

Fig. D.2 presents the production scenarios and their associated rates of return. Similar to the oil price scenarios, the production scenarios represent cases with small changes in the production level as well as the timing effects of those changes. Overall, the production scenarios results are very similar to their counterparts in the oil price section.<sup>37</sup> Here, we still have all three groups of scenarios in addition to an actual production profile scenario. In the first group, we have investigated the effects of having the production level 20% lower or higher in all the years of amortization. Similar to the oil price scenarios, we find that production level 20% lower than contractual in all the years have larger absolute effects in terms of

<sup>36</sup> This scenario has resulted in the same ROR as in the actual oil price scenario. That is due to the fact that the actual oil price in the year of the start of the repayment is lower than contractual, and it is higher in the second year of the start of the repayment.

<sup>37</sup> Except for the actual production profile scenario.

reducing the IOC's ROR compared to a scenario with production level 20% higher than contractual in all the years. In the second group, we have shown the effects of changing the production level for one year in different points of time. We find that changes in the last year of amortization have no effects on the rate of return. However, 20% production level lower or higher than the contractual level, in the start year of repayment, could reduce or increase the IOC's ROR to 14.23% or 14.66%, respectively. These effects are slightly higher than the effects of similar such changes in the middle year of amortization. Therefore, regarding the timing of changes, we find the start of the repayment year as the most important year of the amortization period. In the third group, we have two similar scenarios in which the production level for two consecutive years from the start of repayment is higher in the first year and lower in the second year (or vice versa). For this scenario, we find similar results as described for the oil price. Finally, our actual production profile scenario shows that production profile by itself can reduce the IOC's ROR to 12.73%.

### D.3. LIBOR

Fig. D.3 presents the LIBOR related scenarios and their associated rates of return. Similar to the oil price and production parameters, in several groups of scenarios, we investigate the effects of changes in the LIBOR on the rate of return and the effects of the timing of those changes.

In the first group of scenarios, the LIBOR trend is different from the contractual level in all the years of amortization. We find that LIBOR 20% lower than contractual in all the years have smaller absolute effects in terms of reducing the IOC ROR compared to a scenario with LIBOR 20% higher than contractual in all the years. In this group, we also have two paired increasing/decreasing trend scenarios. The scenario with simple increasing trend has slightly higher absolute effects in increasing the IOC ROR compared to a simple decreasing scenario. Also, a scenario with an increasing trend from the beginning followed by a decreasing trend from the middle year has larger absolute effects compared to a scenario when the decreasing trend starts from the beginning followed by an increasing trend from the middle year.

In the second group of scenarios, we have LIBOR one year 20% lower or higher than the contractual level. Similar to oil price and production parameters, the timing of changes in the LIBOR is important since, for example, LIBOR 20% lower or higher than contractual in the first and last year of the amortization period has no effects on the IOC ROR. In contrast, similar changes in the middle year of the amortization period could change the ROR to 14.29% or 14.59%, respectively. In the start of repayment LIBOR 20% lower or higher than contractual could change the ROR to 14.26% or 14.63%, respectively, compared to a 14.44% contractual level.

In the third group and in two scenarios, we have the LIBOR 20% lower or higher than the contractual level in the two consecutive years with the start of the repayment. However, these changes have almost no effects on the rate of return. Interestingly, our actual LIBOR scenario reveals that reduction in the LIBOR could reduce the IOC ROR to 12.72%.

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